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GROUNDWATER CONTAMINATION RISK ASSESSMENT: A CASE STUDY OF THE HAT YAI BASIN

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Abstract: *For decades, Hat Yai city, a major city in southern Thailand, has experienced significant increase in population, urbanization and industrialization which leads to major concerns of over utilization of groundwater and potential of groundwater contamination. An objective of this study was to conduct groundwater contamination risk assessment for the Hat Yai basin area. Hazard Ranking System was used for assessing contaminant potential and DRASTIC method was used to determine aquifer vulnerability. Risk index of groundwater contamination was defined by a product of contaminant potential and aquifer vulnerability. Based on the results of this study, the risk index of groundwater contamination was found to be 4 out of 25 which indicated that, for the Hat Yai basin , in general, there was very low risk of groundwater contamination.*

Key Words: ***Risk Assessment / Groundwater Contamination /Hat Yai Basin***

1. INTRODUCTION

The Hat Yai basin is located in the southern part of Thailand. The Hat Yai basin mainly includes Hat Yai city and some other districts within Songkhla province with total population of 468,570 people. It is approximately 70 km in the north-south direction from the mountainous area of the Thai-Malaysian border on the southern boundary to the Songkhla Lake on the northern boundary and about 30 km in the east-west direction from Buntad Mountain on the western boundary to Korhong Mountain on the eastern boundary [1,2] as shown in Fig. 1. Groundwater is mainly withdrawn from three main unconsolidated aquifers namely; Hat Yai aquifer, Kutao aquifer, and Korhong aquifer [3].

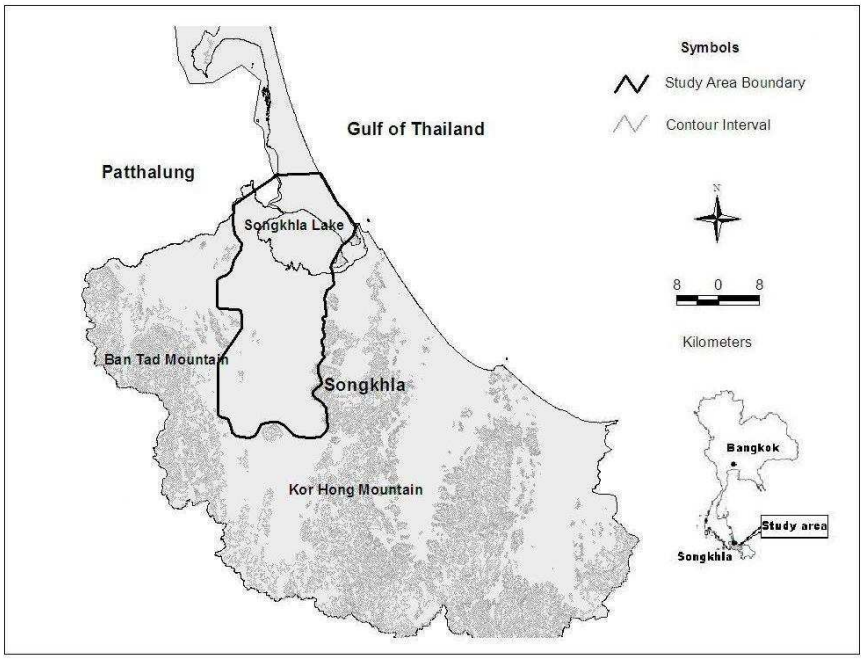

Fig. 1. *Map of Hat Yai basin*

For decades, Hat Yai city, a center of business and tourism in southern Thailand, has experienced significant increase in population, urbanization and industrialization which leads to major concerns of over utilization of groundwater and potential of groundwater contamination. An objective of this study was to conduct groundwater contamination risk assessment for the Hat Yai basin area by Thai Department of Groundwater Resources Standard (2008).

2. METHODOLOGY

Based on Thai Department of Groundwater Resources Standard, groundwater contamination risk index was defined by a product of contaminant potential and aquifer vulnerability [4]. The hazard ranking system (USEPA, 1992) [5] was used for assessing contaminant potential and DRASTIC method (Aller et al., 1987) [6] was used to determine aquifer vulnerability. Risk assessment for groundwater contamination in term of risk index as proposed by Gonzalez, et al. 1997 [7], is shown in Eq. 1.

$$R = L \times V \tag{1}$$

where R is groundwater contaminant risk index, L is contaminant potetial level and V is aquifer vulnerability level.

3. CONTAMINANT POTENTIAL ASSESSMENT

For Hazard ranging system according to USEPA (1992)[5]., six pollutant sources were considered; land fill, gas station, industrial factory, wastewater treatment system, mining and agriculture. Contaminant potential level for each source is rated from one (i.e., very low potential rate) to five (i.e., very high potential rate) which are equivalent to percentage of potential score from less than 45% to greater than 90%, respectively, as show in Table 1.

Table 1. *Potential level and potential rate of contaminant potential assessment [4].*

Percentage of potential score	Potential level (L)	Potential rate
<45	1	Very low
46-60	2	Low
60-75	3	Moderate
76-90	4	High
>90	5	Very high

In this study, the percentages of contaminant potential scores were determined based on available data of Hat Yai landfill (e.g., landfill system, waste volume per day, waste composition etc.) [8], the distance from gas station to water source [9], type of mineral and distance from mine to public water source [9]. Other data such as concentration of pesticides, wastewater volume, sludge treatment system and quality of treated water for wastewater system and industrial factories were collected by the authors. The positions of all pollutant sources in the Hat Yai basin are shown in Fig. 2. Results of contaminant potential assessment of the Hat Yai basin are tabulated in Table 2. According to USEPA (1992) (Table 1.), landfill source provided the highest percentage of potential score of 76 whereas gas station source indicated the lowest score of 40 which were categorized as level 4 and 1, respectively. Although percentages of potential score are slightly higher than that of gas station, wastewater treatment system and agriculture source were also categorized as level 1. The landfill highest level was due to some important factors such as, waste composition, waste volume per day, landfill system and area of landfill. In contrary, factors affecting contaminant potential level of the gas stations such as, wall thickness of gas tank and distance to water source provided low potential scores resulting in low contaminant potential level.

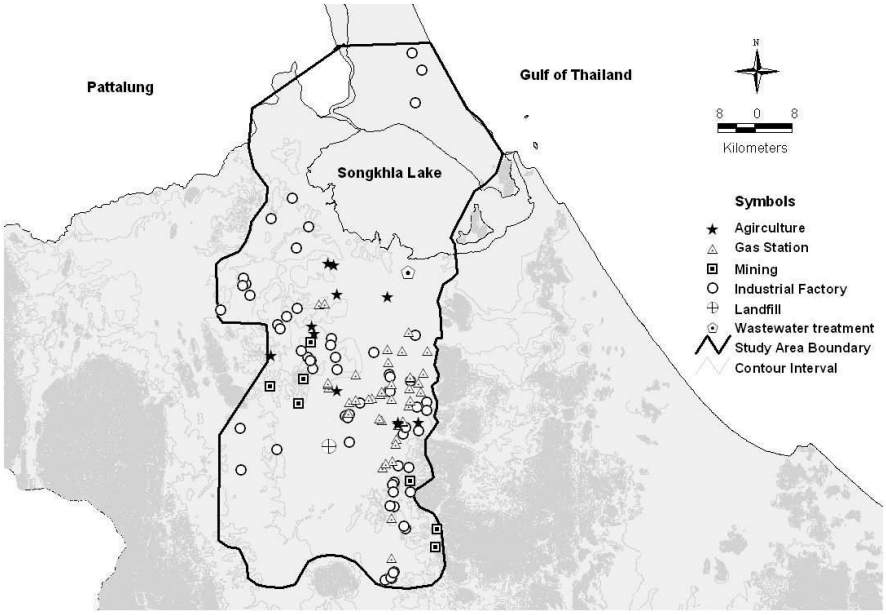

Fig. 2. *Position of pollutant sources in the Hat Yai basin.*

Table 2. *Result of contaminant potential assessment.*

Pollutant sources	Potential score	Possible maximum score	% of potential score	Level
Landfill	79	104	76	4
Gas station	6	15	40	1
Industrial factories	30	62	48	2
Wastewater treatment system	26	62	42	1
Mining	32	45	71	3
Agriculture	-	-	-	1

Pesticides contaminated groundwater was used in the rating of contaminant potential level. In the study area, very low concentration of pesticides was observed, thus it was categorized as level 1.

4. AQUIFER VULNERABILITY ASSESSMENT

Aquifer vulnerability was assessed using DRASTIC method [6]. DRASTIC index was determined using aquifer properties such as depth to water table (D), net recharge (R), aquifer media (A), soil media (S), topography (T), impact of the vadose zone media (I) and hydraulic conductivity of the aquifer (C) as shown in Eq.2.

$$D_rD_w+R_rR_w+A_rA_w+S_rS_w+T_rT_w+I_rI_w+C_rC_w = \text{DRASTIC Index} \quad (2)$$

where subscript r indicates parameter rating ranging from 1 to 10, and subscript w indicates parameter weight ranging feom 1 to 5. Thus possible maximum and minimum scores for DRASTIC index are 226 and 23 respectively.

Aquifer properties of the Hat Yai aquifer, a major aquifer of the area, are shown in Table 3 [9, 10]. The corresponding DRASTIC index calculated using data in Table 3 and Eq. 2 are shown in Table 4. Only two DRASTIC index values of 98 and 108 were found for the Hat Yai basin and can be categorized as very low aquifer vulnerability level. This was because the study area has practically the same geology and hydrogeology. However, the only parameter that resulted in different DRASTIC index was “depth to water table” as shown in Table 3. Furthermore, when compare the result index of this study with maximum index that is low which can be explained that two important parameters was involved consists of impact of vadose zone media and depth to water table that are 5 of weight but rating is not over 5 as show in Table 4. The depth to water table was about 25 m at the center of the basin (i.e., Dr = 3) while Dr = 5 for boundary areas (i.e., depth of water table was 12 m.)

Table 3. Weight, rating and score of each parameter.

Parameter	Data of Hat Yai basin	Weight	Rating	Score
Depth to water table	12-25 m	5	3 and 5	15 and 25
Net recharge	71-140 mm/yr	4	4	16
Aquifer media	Sand and gravel	3	9	27
Soil media	Clay	1	2	2
Topography	Percentage slope	1	9	9
Impact of the vadose zone media	clay	5	1	5
Hydraulic conductivity of the aquifer	1×10^{-4} to 1×10^{-6} m/sec	3	8	24

Table 4. *DRASTIC index and score of each parameter for aquifer vulnerability of Hat Yai basin.*

Pollutant Source	D	R	A	S	T	I	C	DRASTIC Index
Hat Yai Municipal Landfill	15	16	27	2	9	5	24	98
Gas Stations	25	16	27	2	9	5	24	108
Industrial Factories	25	16	27	2	9	5	24	108
Wastewater Treatment System	15	16	27	2	9	5	24	98
Mining	25	16	27	2	9	5	24	108
Agriculture	25	16	27	2	9	5	24	108

5. GROUNDWATER CONTAMINATION RISK ASSESSMENT

For the Hat Yai basin, aquifer vulnerability, potential contaminant and risk index values obtained in this study are tabulated in Table 5. and criteria for risk rate are shown in Table 6. Based on the results of this study, the risk index of groundwater contamination ranged from 1 to 4 which indicated that the risk of groundwater contamination in the area is very low which mainly due to very low level of aquifer vulnerability resulting from a thick clay layer above the Hat Yai aquifer.

Table 5. *Hazard Rating Score of the Hat Yai basin.*

Pollutant sources	Aquifer vulnerability (V)	Contaminant potential (L)	Risk index (R)	Risk rate
Hat Yai Municipalities Landfill	1	4	4	Very low
Gas Stations	1	1	1	Very low
Industrial Factories	1	2	2	Very low
Wastewater Treatment System	1	1	1	Very low
Mining	1	3	3	Very low
Agriculture	1	1	1	Very low

Table 6. *Risk rate and risk index for risk assessment.*

Level	Risk rate	Risk index
1	Very low	1-5
2	Low	6-10
3	Moderate	11-15
4	High	16-20
5	Very high	20-25

6. CONCLUSION

Groundwater contamination risk assessment for the Hat Yai basin was conducted according to Thai Department of Groundwater Resources Standard. The following conclusion can be made.

1. Contaminant potential assessment results of the Hat Yai basin ranged from level 1 to 4. The landfill source provided the highest level of 4 whereas gas station source, wastewater system source and agriculture source indicated the lowest level of 1. In addition, industrial factory source and mining source were found to be level 2 and level 3, respectively.

2. The aquifer vulnerability of all pollutant sources was very low (level 1). This was due to the fact that the area has the same geology and hydrogeology. Particularly, the thick clay layer (aquitard) above Hat Yai aquifer was the main factor resulting in low aquifer vulnerability of the area.

3. Risk index of groundwater contamination was in range of 1 to 4 out of 25 which indicated that, for the Hat Yai basin, there was very low risk of groundwater contamination.

7. ACKNOWLEDGEMENT

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